Chapter 15

In-pond Raceways

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The concept of the in-pond raceway (IPR) was simple. It would be a system, like cages, that could be adapted to almost any body of water but with the advantage of controlled water movement to improve the water quality and allow for increased stocking density, thereby increasing total production per unit area. Many researchers and aquaculture entrepreneurs have looked at the vast amount of water impounded or potentially available in rivers, bays, and estuaries and have seen opportunities to produce fish. Cages, especially in private impounded waters, seemed to be problematic because of disease outbreaks, poor localized water quality, and slow growth. These problems often appeared to be related to poor water circulation through the cage (Masser & Woods 2008).

Flow-through systems, such as raceways (see chapter 9) tend to have fewer water quality issues than most other culture systems. The constant exchange of water removes metabolites from the culture area and allows increased stocking rates and production rates per unit area compared to cages and open ponds. Traditional raceways have to be located on springs or creeks with sufficient gradient, and these constant flowing water sources are exceedingly site limited. The largest drawback of traditional raceways, aside from limited suitable locations, is the constant discharge of wastes into the receiving surface waters of the state. The discharge of these wastes has caused public concern and led to the enactment of strict environmental regulations. Additionally, the high water flow rates common in raceway systems reduce the concentration of these waste products making them difficult to capture or mediate before leaving the site.

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The idea of placing a fish in some type of box-like enclosure suspended in a body of water and moving water through it is not new, and several designs have been developed and patented (Collamer 1923; Fremont 1972; Fast 1977; Long 1990; Caillouet 1995). These designs all utilized some type of pumping system to move water through a box or raceway.

15.1 Development of the in-pond raceway

In the early 1990s, an IPR design was developed at Auburn University. The design used airlift pumps to move water through a box-like culture area. The raceway was rectangular and suspended from a floating pier. Airlifts were placed at one end of multiple raceways and water was pumped through the airlifts into the raceways at the surface. Water was discharged from the raceways along the bottom on the opposite end from the airlifts. The water discharged through a solids-settling chamber and then flowed back into the impoundment (Masser 1997; fig. 15.1).

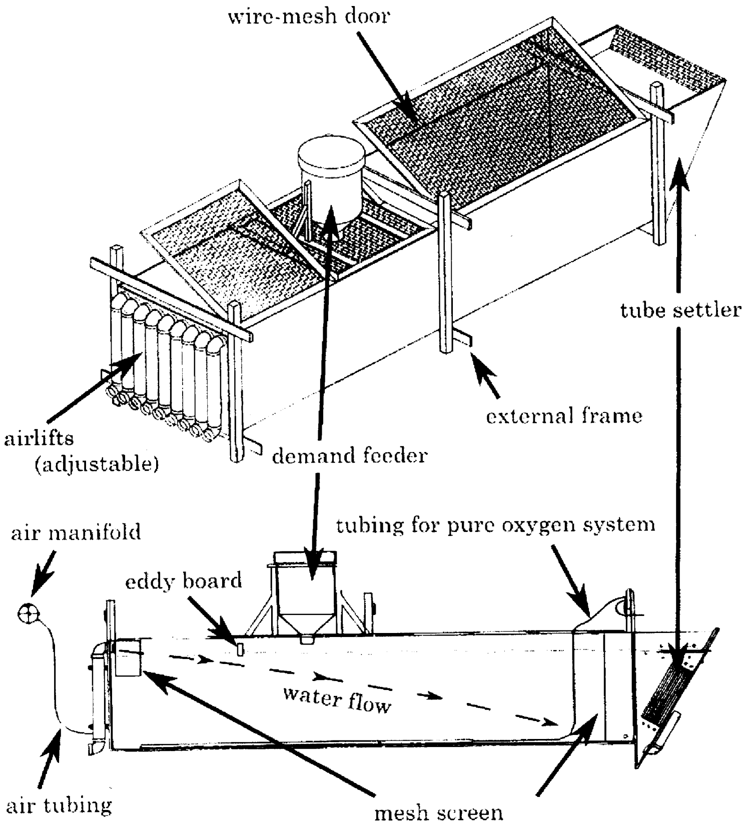

Figure 15.1 Diagram of the in-pond raceway (IPR) and its components.

The construction of an IPR was relatively simple as well. The raceway box itself was constructed from 1.3-cm thick (0.5-in thick) marine plywood or 0.7 cm (1/4 inch) plastic sheeting. These were attached to a treated wooden frame and suspended from a floating dock. Cage mesh-type materials (plastic-coated, welded wire mesh 2.54 cm × 1.27 cm) were used across the airlift openings and the discharge areas to keep fish inside the raceway. Cage mesh materials were also used to partition the raceway into sections for polyculture or segregation of different size classes of fish (Masser 1997).

The airlifts were constructed of 7.6-cm (3-in) diameter PVC pipe. They were attached to plywood or plastic sheets and aligned so that they filled the space across the front of the raceways. The bank or array of airlifts was set in a vertical track so they could be raised or lowered to regulate water flow. When properly designed and positioned, a single 7.6 cm (3 in) airlift could pump approximately 230 L (60 gallons) of water per minute, and nine airlifts were used per raceway. Air was supplied to the airlifts from a regenerative air blower. A one-horsepower blower could supply sufficient volume for approximately twenty-seven individual airlifts. Water exchange rates could be adjusted from as low as three exchanges per hour to as many as nine exchanges per hour, depending upon the height of the water discharge tubes above the water surface. Capacity to reduce the flow rate is important when fingerlings are small and during periods of cooler water temperatures (e.g., overwinter). An eddy board was placed across the width of the raceway approximately 1.8 m (5 ft) from the airlift discharge. This board deflected the water flow downward and created an eddy behind it, which functioned as the feeding area. Feed placed behind the eddy board would stay trapped by the eddy currents and not be washed out of the raceway (fig. 15.2).

The advantage of the airlift system was not only high volumes of water moved but also some degree of aeration. Although airlifts are not very efficient oxygen transfer systems in relative terms, they become more efficient when dissolved

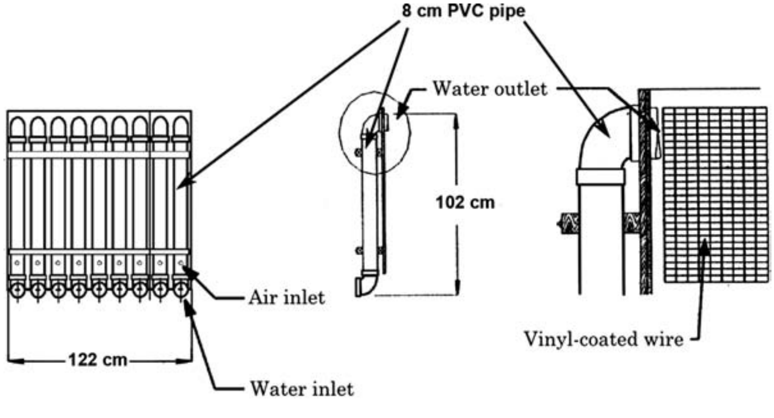

Figure 15.2 Diagram of IPR airlift array.

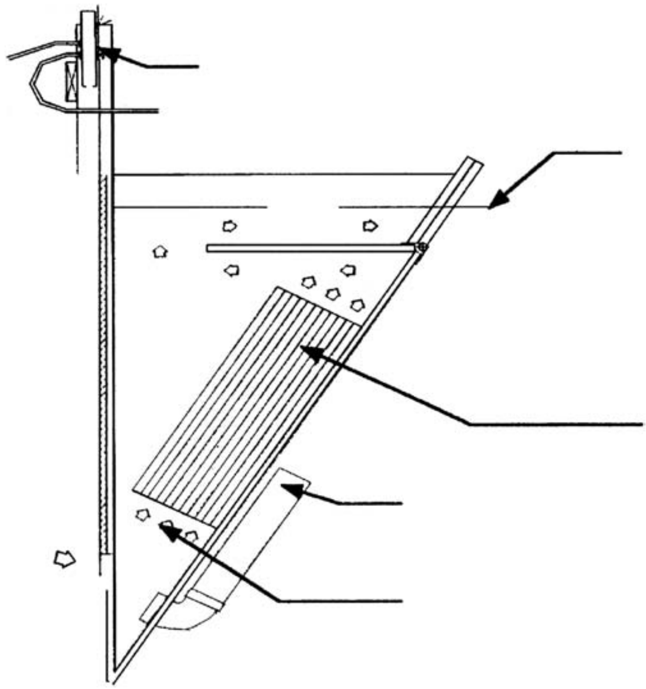

Figure 15.3 Diagram of IPR tube settler.

oxygen concentrations are low (Boyd 1990). In the Auburn study, the airlifts maintained dissolved oxygen concentrations in the high-density raceways above 3 mg/L, even if the impoundment they floated in had oxygen concentrations below 2 mg/L (Masser 2004).

Solid waste collection was attempted through either quiescent-cone or tube-type settlers attached to the back of the raceway (fig. 15.3). These passive methods captured a portion of the solid wastes excreted by the fish, which were then removed from the system. This lessened the negative impact on the water quality of the impoundment. Analysis of the dried solids confirmed that high percentages of nitrogen and phosphorous were collected (Hawcroft 1994; Yoo *et al.* 1995; Bernardez 1995; Martin 1997).

15.2 Stocking and feeding

Species that have been cultured in an IPR include channel catfish (*Ictalurus punctatus*), blue catfish (*Ictalurus furcatus*), and the channel × blue hybrid, as well as Nile tilapia (*Oreochromis niloticus*), hybrid striped bass (*Morone saxatilis* × *M. chrysops*), bluegill sunfish (*Lepomis macrochirus*), yellow perch (*Perca flavescens*), and rainbow trout (*Oncorhynchus mykiss*). Channel catfish and Nile tilapia were successfully polycultured in experiments at Auburn University (Bernardez 1995). Stocking rates in the IPR varied from 326 to 543 fish

per cubic meter (9 to 15 fish per cubic foot) of culture area. Throughout the experiments at Auburn University with channel catfish, no differences in growth rates or food conversion rates were observed at these stocking rates (Masser 1997).

Feeding a nutritionally complete diet is essential in an IPR, because the fish get no natural food items from the environment. Floating feed was given to allow observation of feeding activity and to keep feed trapped behind the eddy board. When hand-fed, the daily feeding rates were based on commonly used feeding tables for the species cultured. However, demand feeders proved to be just as efficient (i.e., feed conversion) as hand-feeding channel catfish and reduced labor requirements (Bernardez 1995).

15.3 Backup systems and disease treatments

The IPR is an energy-dependent system. If a blower fails and water flow stops, the raceways will become oxygen limited in a matter of minutes. Backup or emergency systems are essential if the system is to be successful. Power and equipment failure backup, as well as notification systems similar to those used in recirculating aquaculture systems (RAS), have been utilized in IPR systems. A simple oxygen supply system was incorporated into the Auburn IPR design using cylinders of pure oxygen connected to an electric solenoid switch. The solenoid remained closed, stopping oxygen release from the bottles unless the electricity went off. When the electricity supply was interrupted, the solenoid opened to allow pure oxygen to be released into the raceways through micropore tubing (i.e., the same as used in hauling tanks; Hawcroft 1994; Yoo *et al.* 1995). This system can successfully maintain fish in the IPR for several hours or until electric service is restored.

Another benefit of oxygen backup systems in IPR is during disease treatments. With the blowers off and water flow stopped, the emergency oxygen system can be used to maintain the fish. The raceway then becomes a static tank that can be dosed with precise bath-type treatments (e.g., potassium permanganate or formalin). These treatments are inexpensive and effective methods for combating certain bacterial and protozoal diseases.

15.4 Comparison to other culture systems

The general advantages and disadvantages of the IPR compared to other systems are summarized in table 15.1. In the following sections, *traditional raceways* refers to land-based flow-through raceways, while RAS refers to recirculating aquaculture systems.

In terms of production, the Auburn IPR averaged a yield of approximately 136 kg/m^3 (8.5 lb/ft^3) of catfish and tilapia (Wilcox 1998; Masser 1999). These densities have been achieved by some cage and RAS operations but are not

Table 15.1 Comparison of IPR with other culture systems.[1]

Culture system production, environmental, and economic comparison data	IPR	Cage	IPR	Pond	IPR	Traditional Raceways	IPR	RAS
Production Features								
Higher stocking density and carrying capacity	+		+		=	=	+	
Feed conversion ratio (FCR)	+		+		=	=	=	=
Production yields per unit area	+		+		=	=	+	
Overwintering of certain species (e.g., catfish)	=	=		+		+		+
Economic Features								
Reduced labor requirements in regard to accessibility, feeding, grading, harvesting, and treatment of diseases	+		+		=	=	+	
More economically efficient & produces fish at reduced costs	+		+			+	+	
Environmental Features								
Better water quality, particularly dissolved oxygen (DO) and ammonia concentrations	+		+			+		+
Environmentally superior for solid waste collection and removal	+		+		+			+

Notes:
[1] Better system indicated by +; Similar systems indicated by = .

common. The feed conversion ratio (FCR) averaged 1.5:1 in research trials at Auburn (Wilcox 1998; Masser 1999).

Economic feasibility of IPRs is based on Auburn University trial data (table 15.2), which showed IPRs to be more economically efficient than ponds and cages. The IPR design and greater accessibility simplified feeding, grading, harvest, and disease treatments compared to other systems. This reduced labor requirements compared to ponds or RAS. The IPR also had lower production costs than are typical with RAS. The modified IPR in west Alabama even appears to have lower production costs than standard commercial catfish ponds (Brown *et al.* 2010).

The IPR, with its system of passive settling devices, is environmentally superior in terms of solid waste removal when compared to cages, ponds, and traditional raceways, which do little to capture wastes; however, IPRs are still not exceptionally efficient. As in ponds, cages, and traditional raceways, IPRs rely on natural processes within the receiving impoundment to process liquid wastes and solid wastes that are not removed by the passive settlers. Recirculating systems, with active solids removal and biological filters, are much more efficient at removal of waste products (Losordo *et al.* 1999).

Table 15.2 Economic comparisons between IPR, cages, and open-pond catfish culture (0.4 ha pond; Bernardez 1995).[1]

	Open-pond[2]	Cage	IPR
Assumptions			
Yield (kg)	1,730	1,286	2,433
Death loss (%)	6	10	10
Feed conversion	1.8	1.6	1.45
% Protein feed	32	36	36
Economic parameters (US$)			
Variable costs	3,135.63	2,391.27	4,160.25
Fixed costs	787.72	850.16	1,111.26
Total costs	3,923.35	3,241.43	5,271.51
Breakeven price (US$ per kg)			
To cover variable costs	1.81	1.86	1.71
To cover total costs	2.27	2.52	2.17

Notes:
[1] Pond construction and management costs have not been included in the budgets.
[2] Open-pond production yields are based on actual average production values observed in the catfish industry in Alabama.

15.5 Sustainability issues

The IPR system appears to be more environmentally sustainable than cages, raceways, and intensive open-pond production ponds. The IPR system is slowly being adapted to larger-scale operations and appears to be highly efficient at producing fish (Brown *et al.* 2010). Using hybrid catfish, a modified IPR in west Alabama has reached harvest densities of over 200 kg/m^3 and estimated production costs below the current average pond production costs. If this adoption continues, the IPR could replace traditional ponds for culture of many finfish species.

15.6 Future trends

Research still needs to be conducted on the IPR. Particularly, cost-effective solid and liquid waste reduction methods need to be evaluated and further developed. The current adaptations needed for scaling up the IPR system to more commercial sizes need to be further studied and economically evaluated.

15.7 References

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